ALEX(01)-TR-77-10

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SEISMIC DATA PREPARATION PROCEDURES

TECHNICAL REPORT NO. 10

VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

Prepared by
A. William Schmidt and Kimberly S. Wilson

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Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 7F10
ARPA Order No. 2551

20 October 1977

Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract Number F08606-77-C-0004.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SEISMIC DATA PREPARATION PROCEDURES		5. TYPE OF REPORT & PERIOD COVERED Technical
		6. PERFORMING ORG. REPORT NUMBER ALEX(01)-TR-77-10 ✓
7. AUTHOR(s) A. William Schmidt and Kimberly S. Wilson		8. CONTRACT OR GRANT NUMBER(s) F08606-77-C-0004 ✓
9. PERFORMING ORGANIZATION NAME AND ADDRESS Texas Instruments Incorporated ✓ Equipment Group Dallas, Texas 75222		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS VELA T/7705/B/ETR
11. CONTROLLING OFFICE NAME AND ADDRESS Advanced Research Projects Agency Nuclear Monitoring Research Office Arlington, Virginia 22209		12. REPORT DATE 20 October 1977
		13. NUMBER OF PAGES 54
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Air Force Technical Applications Center VELA Seismological Center Alexandria, Virginia 22314		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

ARPA Order No. 2551

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Seismology	Edit
Data preparation	Event
Long-Period	Computer program
Short-Period	Magnetic tape

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The computer programs currently being used to prepare seismic data for analysis on the PDP-15 computer, and the flow of data through them, are described briefly. The programs are being run by Texas Instruments Incorporated on the IBM 360/44 at the Seismic Data Analysis Center. New programs developed during the contract period are described in some detail. Some suggestions for future work are provided.

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ABSTRACT

The computer programs currently being used to prepare seismic data for analysis on the PDP-15 computer, and the flow of data through them, are described briefly. The programs are being run by Texas Instruments Incorporated on the IBM 360/44 at the Seismic Data Analysis Center. New programs developed during the contract period are described in some detail. Some suggestions for future work are provided.

ACKNOWLEDGMENTS

I gratefully acknowledge K. S. Wilson for writing TIKSLPED, for her considerable assistance in writing TISROPRG, TISROSPE, and TITRIEDT, and for her contribution to the text of this report (Appendix A). The flow charts appearing in this report were prepared by H. R. Scott. I acknowledge D. L. Lashmit for his help in writing NEWMAKE. Guidance, and suggestions for program improvements, were provided by R. L. Sax, A. C. Strauss, W. H. Swindell, and D. Sun.

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SECTION I

INTRODUCTION

This task concerns development of computer programs on the IBM 360/44 computer at the Seismic Data Analysis Center (SDAC). The programs prepare seismic data for analysis on the PDP-15 computer by extracting selected events, removing the mean from each trace, and, if desired, rotating the data and beamforming them. The input data for these programs come, in part, from magnetic tapes sent in from the field. The goal is to put the data onto tapes in event/station/component form, suitable for input into the Interactive Seismic Processing System (ISPS) on the PDP-15 (Ringdal, et al., 1975).

This preparation is usually done in three steps. The field tapes are processed first by edit programs, to translate the raw data from integer or gain-ranged format to floating-point format, and to produce other tapes, called edit tapes. The edit programs are event-driven and have the effect of eliminating most non-event data. Thus, a considerable reduction in data volume occurs. The edit programs also write information about array configuration, event distance and azimuth, etc., in an event header record on the edit tape. The edit programs contain logic to re-try and eventually skip over parity errors. Thus, a considerable increase in data quality is realized.

The data are further prepared by programs known as "gen" programs. The gen programs remove the means of the traces. They rotate the data, if desired, from Tri-Axial or Vertical-North-East format to Vertical-Transverse-Radial orientation. Some gen programs have a capability to apply various filters to the data. In the case of array gen programs, sites selected by the analyst can be formed into beams. Output from the gen programs is a gen tape, or punched cards. The final step in the data preparation consists of copying the data onto a 7-track tape, in a format compatible with the off-line PDP-15 program CDBASE. CDBASE initializes the Event Data File for ISPS (see Ringdal, et al., 1975). The entire data preparation process is summarized in Figure I-1.

The reasons for the data preparation being done on the IBM machine instead of the PDP-15 include:

- The relatively high down time of the PDP-15
- Its core size (insufficient for remultiplexing and beamforming)
- The lack of a capability to read nine track, 1600 bits per inch, tapes on the PDP-15.

Currently, there are 18 varieties of seismic data available on field tapes at the SDAC. Tables I-1 and I-2 illustrate the current processing capability.

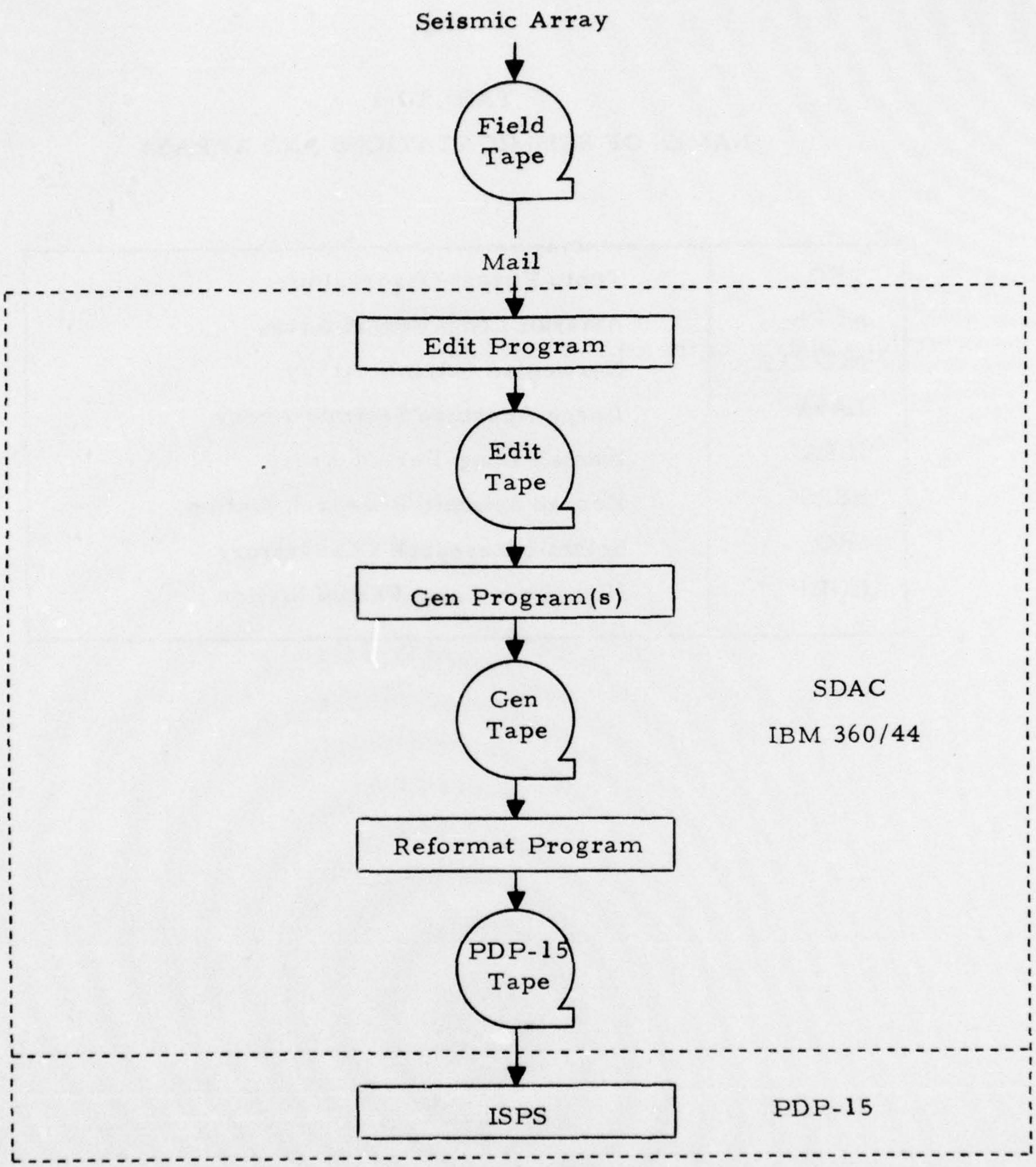

FIGURE I-1

SEISMIC DATA PREPARATION

TABLE I-1

NAMES OF SEISMIC STATIONS AND ARRAYS

TFO	Tonto Forest Observatory
ALPA	Alaskan Long-Period Array
NORSAR	Norwegian Seismic Array
LASA	Large Aperture Seismic Array
ILPA	Iranian Long-Period Array
KSRS	Korean Seismic Research Station
SRO	Seismic Research Observatory
HGLP	High-Gain Long-Period Station

TABLE I-2

DATA PREPARATION PROGRAM STATUS

Data Source	LP/SP	Currently Producing Data	Edit Program Name	Gen Program Name
TFO	LP	No	TIQCEDIT	TITDFILT
ALPA (until 1970)	LP	No	TIQCEDIT	TITDFILT
ALPA (1971-75)	LP	No	TIQCEDIT	TITDFILT
ALPA (after 1975)**	LP	Yes	TITRIEDT	TITDFILT
NORSAR (until 1975)	LP	No	TINOREDT	TITDFILT
NORSAR (after 1975)**	LP	Yes	TITRIEDT	TITDFILT
NORSAR (until 1975)	SP	No	NORSPOUT*	SIGSPECT* NORSPEAR* DATAPREP
NORSAR (after 1975)**	SP	Yes	None	None
LASA (until 1975)	SP	No	None	None
LASA (after 1975)**	SP	Yes	None	None
LASA (until 1975)	LP	No	TILASEDT	TITDFILT
LASA (after 1975)**	LP	Yes	TITRIEDT	TITDFILT
ILPA	LP	Yes	TIILPEDT	TITDFILT
KSRS	LP	Yes	TIKSLPED	TITDFILT
KSRS	SP	Yes	TIKSPED*	TIKSPEAR* TINOISE
SRO	SP	Yes	TISROSPE	TISROSPE
SRO	LP	Yes	TISROEDT TISROPRG	TISROGEN TISROPRG
HGLP	LP	No	TILXEDIT*	TILXGEN*

* Currently available only under the Disc Operating System (DOS).

** On January 1, 1976, a new library tape format came into use. See Appendix A.

SECTION II

PROGRAMS WRITTEN DURING 1977

Several improvements were made to the existing data preparation software during 1976-1977. Several of the programs were converted from the Disc Operating System (DOS) to the Programming System (TS44). Also, six new programs were written. Of particular note are TISROPRG, an example of combining an edit program designed to handle data from more than one seismic array. The new programs are described on the following pages.

A. TISROPRG

TISROPRG is a combination edit, data preparation, and plotting program for long-period Seismic Research Observatory (SRO) data. It operates on data from single SRO stations only. TISROPRG is the result of combining four previously existing programs: SROPUNCH, TISROEDT, TISROGEN, and SROPLOT. Several of the capabilities of TISROGEN were not included in TISROPRG, in order to save computer time and memory space. Briefly, the lost capabilities included taking of Fourier transforms, generation of noise matrices, noise analysis, two channel Wiener filtering, and two component Rayleigh phase shift and sum. None of these capabilities were needed for the SRO evaluation study.

The SRO data processing sequence has been modified when using TISROPRG. The primary output from TISROEDT is an edit tape, which is also the primary input to TISROGEN. TISROPRG does not produce an edit tape. Use of this program results in saving over half the Central Processing Unit (CPU) time, and over half of the core space, as compared to running the four parent programs. The input cards are described in Table II-1. The output tape is in the LXGEN format (see Benno, et al., 1971), and is identical to the tape produced

TABLE II-1

TISROPRG INPUT CARDS
(PAGE 1 OF 3)

The input cards to TISROPRG are divided into three groups: tape initialization card (one card); event specification cards (two cards per event); and plot specification cards (one card per plot tape, plus one card for each event to be plotted). The cards must be in the following format:

Card Type	Columns	Data* Type	Description
1	1-12	A	'OUTPUT TAPE='
	13-18	A	Output tape number. Also known as the gen tape.
	19-26	A	', OPTION='
	27-30	A	Output tape option, to be used in the call to TIINPT.
	31-55		Not used.
	56-60	A	'SKIP='
	61-65	I	Number of data files to be skipped, on the output tape.
	66-80		Not used.
2	1-8	I	Month/Day/Year of event origin.
	9		Not used.
	10-17	I	Hour/Minute/Second of event origin time.
	18-20		Not used.
	21-25	F	Event latitude in decimal degrees (N=+).
	26-29		Not used.
	30-35	F	Event longitude in decimal degrees (E=+).
	36-37		Not used.

* A = Alphanumeric I = Integer F = Floating Point

TABLE II-1

TISROPRG INPUT CARDS
(PAGE 2 OF 3)

Card Type	Columns	Data* Type	Description
2	38-40	F	Bodywave magnitude.
	41-42		Not used.
	43-45	I	Depth (km.).
	46	I	NORSAR quality
	47-50		Not used.
	51-70	A	Region name.
	71-80		Not used.
3	1-5	I	Event identification number.
	6-10	I	Sub-region number.
	11-12		Not used.
	13-15	A	*Information source.*
	16-20		Not used.
	21-35	I	Site selection table. Column (20+n) should be 1 if data from SRO n is to be processed; 0 if it is not.
	36-80		Not used.
4	1-50		Not used.
	51-53	A	'END'
	54-80		Not used.
5	1-6	A	Plot tape number.
	7-8		Not used.
	9-10	I	Number of plots to be put on this plot tape.
	11-80		Not used.
6	1-10	F	FLO.
	11-20	F	FHI.

* A = Alphanumeric I = Integer F = Floating Point

TABLE II-1

TISROPRG INPUT CARDS
(PAGE 3 OF 3)

Card Type	Columns	Data* Type	Description
6	21-30	F	TAPER.
	31-35	I	Start time.
	36-40	I	Gate length.
	41-50	F	Horizontal plot scale factor (seconds/inch).
	51-80		Not used.

* A = Alphanumeric I = Integer F = Floating Point

The divider between the event specification cards and the plot specification cards is a card type 4. If m denotes the number of plots (columns 9-10, card type 5) on a plot tape, there should be m cards of card type 6 following a card type 5. The plot specification cards should be followed by a /*.

by TISROGEN. The subroutines which make up TISROPRG are listed and described below. The logical flow through them is shown in Figure II-1.

<u>Subroutines in TISROPRG</u>

ALQADL	-	Does plot annotation, and processes timing information from the event header. Prepares data for and coordinates Calcomp plotting.
ARTIME	-	Computes P wave, S wave, Love wave, and Rayleigh wave arrival times, and Rayleigh wave duration.
DATPRP	-	Moves data from the input buffer into the plot processing array.
DELTA	-	Computes event distance and azimuth.
EVPROC	-	Sets up processing parameters for SGPREP and SIGOUT, and writes the event header on the output tape.
FILTBP	-	Applies bandpass filter weights.
GENBP	-	Computes filter weights for a bandpass filter with cosine-squared tapered edges.
HEADR	-	Converts data from 16-bit integers to floating point, in place.
INPROC	-	Initializes the output tape.
INPSRO	-	Reads SRO field tapes.
OUTPUT	-	Writes data on a temporary disc file, before the gen part of the program.
PDE	-	Reads input cards, and constructs the event header.
PLTRTN	-	Calcomp plots a waveform. Produces tic-marks to indicate predicted seismic propagation mode arrival times (P, S, Love, and Rayleigh)
QCHECK	-	Performs spike and clipping quality checks, computes channel segment sums and powers, and generates tables of quality check results.

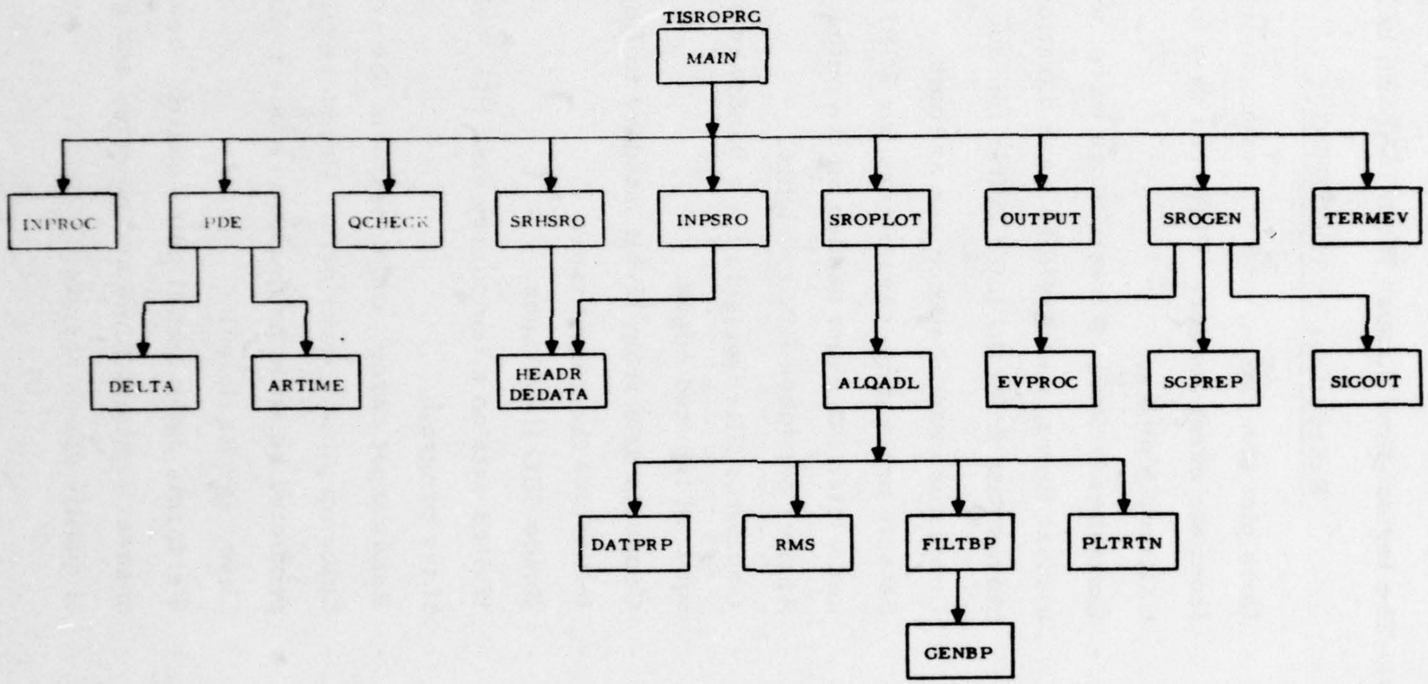

FIGURE II-1

TISROPRG FLOW

RMS - Computes RMS noise in a gate prior to the predicted signal arrival, determines maximum signal amplitude, and calculates signal-to-noise ratio.

SGPREP - Reads data from one temporary disc file, subtracts the trace mean from each point, rotates the data from Vertical-North-East to Vertical-Transverse-Radial form, and writes the data on a second temporary disc file.

SIGOUT - Reads data from a temporary disc file, and writes it on the output tape.

SRHSRO - Searches an SRO field tape for a particular data time.

SROGEN - Fills out a list of processed events and calls SGPREP and SIGOUT.

SROPLT - Initializes and terminates the plot tape. It searches for events that have been processed, on the output tape; reads data, and calls ALQADL.

TERMEV - Computes and prints statistics about an event, and prints quality check information.

B. DATAPREP

DATAPREP is a gen program for NORSAR short-period data recorded prior to 1976. It is the result of combining three previously existing programs: TSMLTSNS, DATAPRP1, and DATAPRP2, which were written in support of the short-period earthquake/explosion discrimination (SPEED) project (Sax, 1976). The input to DATAPREP is limited because the program was written to require 132 input data channels.

As DATAPREP is currently used, the program must be run twice for each event to be processed. The first time through, it remultiplexes the data and aligns the sensors, assuming a plane wave, using a signal start time provided by the analyst. DATAPREP produces a short Calcomp plot (5 seconds of data), either filtered or unfiltered, and with the signal centered, for each sensor in the array. These plots are inspected by the analyst to obtain a list of inoperative channels, noisy channels, and clipped channels. The analyst also selects a more exact signal start time.

This information is provided on input cards, so that DATAPREP can complete its entire processing sequence the next time it is executed. Individual sensor plots are not normally requested from this second run. However, note that the time-consuming data remultiplexing and sensor alignment steps are performed a second time.

Next, an exponential taper is applied to the analyst-selected channels, and they are complex cepstrum beamformed. The beam is smoothed and corrected for system response, absorption, and reverberation noise. Finally, the trace is integrated three times, with cepstrum short-passing after each integration. At the analyst's option, results from each integration can be output on cards or printed. The waveforms are time traces of jerk, acceleration, velocity, and ground motion, respectively.

The card output from this step is in lieu of a gen tape, and is appropriate for input to TAPEMAKE. TAPEMAKE is a card-to-tape reformat program which produces tapes suitable for input to the ISPS on the PDP-15. There is no particular reason that the interface between DATAPREP and TAPEMAKE is via cards, rather than a gen tape.

The primary input to DATAPREP is the edit tape produced by NORSPOUT. The primary output from TSMLTSNS is a tape, which is one of the primary inputs to DATAPRPl. DATAPREP does not produce this tape. Instead, the data are stored on a temporary disc file.

For a further explanation of the processing done by DATAPREP, refer to Sax (1976). The input cards to DATAPREP are described in Table II-2. The subroutines that make up the program are listed and described below. The logical flow through them is shown in Figure II-2.

TABLE II-2

DATAPREP INPUT CARDS

(PAGE 1 OF 3)

Card Type	Columns	Data Type*	Description
1	1-6	A	'INPUT='
	7-12	A	Tape no. of the input tape. (output from NCRSPOUT)
	13-80		Not used.
2	1-12	A	Event name.
	13-16	I	NSHIFT for TSMLTSNS portion of the run.
	17-20	I	Number of points to be plotted for each sensor plot, and for the subarray beams.
	21-25		Not used.
	26	I	PLTSAV. Should be 1 if any plots are to be generated by this DATAPREP run. (0 otherwise)
	27	I	FLTFLG. Should be 1 if the plots for this event should be filtered. Not used if PLTSAV = 0. (0 otherwise)
	28	I	DPFLG. Should be 1 if DATAPRP1 and DATAPRP2 are to be executed for this event. If DPFLG = 1, input cards 3-10 are required. If DPFLG = 0, input cards 3-10 should not be included.
	29	I	QCFLG. Should be 1 if automatic site selection on the basis of data quality is desired. In this case, the logical flags on cards 3 and 4 must all be blank. (0 otherwise).
	30	I	DETFLG. Determines which algorithm is to be used for automatic signal detection. If signal start time is to be set by the analyst, DETFLG should be zero.

* A = Alphanumeric I = Integer F = Floating Point

TABLE II-2

DATAPREP INPUT CARDS
(PAGE 2 OF 3)

Card Type	Columns	Data Type*	Description
2	31-80		Not used.
3	1-12		Not used.
	13-16	I	NSHIFT for the DATAPRP1 portion of the run.
	17-20		Not used.
	21-80	I	Flags for sensors 1-60. 1 if the sensor is to be thrown out; blank if the sensor is to be kept.
4	1-72	I	Flags for sensors 61-132.
	73-76	F	RC (Default is 0.98).
	77-80	F	RCN (Default is 0.98).
5	1-10	F	WTAPER.
	11-20	F	PNOISE.
	21-30	F	PCODA.
	31-80		Not used.
6	1-4	I	Print flags for DATAPRP2. 1 if printout is desired for (1) system response restored, (2) acceleration, (3) velocity, or (4) displacement, respectively.
	5		Not used.
	6-9	I	Punch flags for DATAPRP2. Same scheme as for print flags.
	10-35		Not used.
	36-40	F	T/Q.
7	1-2, etc.	I	Number of smooths to be performed prior to the first integration. The degree of smoothing at each stage is given in columns 3-4, 5-6, 7-8, etc. -- as many as the number in columns 1-2.

* A = Alphanumeric   I = Integer   F = Floating Point

TABLE II-2

DATAPREP INPUT CARDS
(PAGE 3 OF 3)

Card Type	Columns	Data Type*	Description
8	1-2, etc.	I	Number of smooths to be performed during the first integration. Same scheme as above.
9	same	I	Smoothing parameters for second integration.
10	same	I	Smoothing parameters for third integration.

* A = Alphanumeric   I = Integer   F = Floating Point

Summary

Card 1 appears only once per run.

Card 2 appears once per event.

Cards 3 - 10 appear immediately after card 2 whenever DPFLG = 1. If DPFLG = 0, cards 3 - 10 should be omitted.

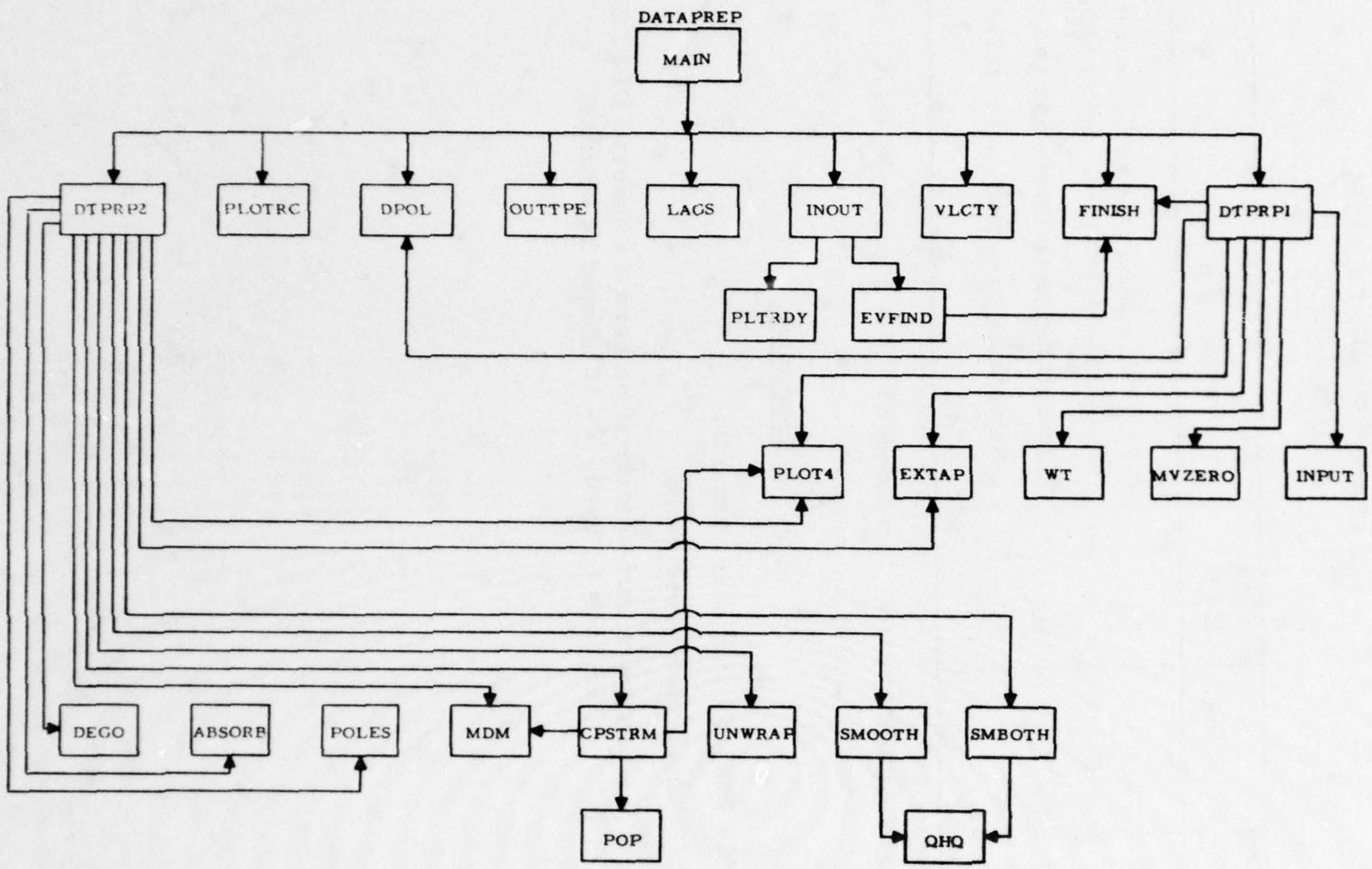

FIGURE II-2

DATAPREP FLOW

Subroutines in DATAPREP

ABSORB	-	Corrects the amplitude and phase of a wavelet for T/Q = constant absorption, in the frequency domain, by a method described by Strick (1970).
CPSTRM	-	Computes and plots the real cepstrum of a log spectrum.
DEGO	-	Removes an echo, specified by number of points delay and reflection coefficient, by deconvolution. Can be used to do numerical integration.
DPOL	-	Removes complex poles in the instrument response curve for short-period VELA seismic network (VELANET) data.
DTPRP1	-	Reads data from disc, corrects for instrument response, applies an exponential taper, and transforms into the log frequency domain.
DTPRP2	-	Performs cepstrum analysis, transforms a log spectrum into the time domain, and does successive numerical integrations, with cepstrum short-passing after each.
EXTAP	-	Applies a taper which exponentially decays, away from a given point.
FINISH	-	Writes an end-of-file on the plot tape, and unloads the input tape.
INCUT	-	Coordinates tape initialization procedures.
EVFIND	-	Reads event specification cards, and searches the input tape for the desired event.
PLTRDY	-	Initializes the plot tape, and puts a title on the plot.
INPUT	-	Reads parameters for DTPRP2, from a card.
LAGS	-	Computes time delays between sensors, given sensor locations.

MDM	-	Remultiplexes a data array from real parts and imaginary parts into complex, or vice-versa.
MVZERO	-	Moves a data array to another area of core, and zeros the original area.
OUTTPE	-	Writes data on disc.
PLOTRC	-	Plots a trace on the Calcomp plotter.
PLOT4	-	Printer-plots a trace.
POLES	-	Restores complex poles in the instrument response curve for short-period VELANET data.
POP	-	Computes filter coefficients deterministically from a set of equations, and applies the resulting filter using polynomial division.
QHQ	-	Smoothes a curve, within a specified interval.
SMBOTH	-	Generates calls to QHQ, to smooth both the amplitude and phase of a spectrum.
SMOOTH	-	Generates a call to QHQ, to smooth just the amplitude part of a spectrum.
UNWRAP	-	Unwraps a continuous complex function onto the correct Riemann surfaces.
VLCTY	-	Computes apparent velocity, given the distance to the source.
WT	-	Applies signal-to-noise ratio weights to channels used for complex cepstrum beamforming.

C. TISROSPE

TISROSPE is a combination edit and data preparation program for short-period SRO data. It operates on data from single SRO stations, only. The primary output is a tape in the LXGEN format. Input cards to TISROSPE are described in Table II-3. The subroutines that make up TISROSPE are listed and described below. The logical flow through them is shown in Figure II-3.

TABLE II-3

TISROSPE INPUT CARDS

(PAGE 1 OF 2)

The input cards to TISROSPE are divided into two groups: tape initialization card (one card); and event specification cards (two cards per event). The cards must be in the following format:

Card Type	Columns	Data Type*	Description
1	1-12	A	'OUTPUT TAPE='
	13-18	A	Output tape number. Also known as the gen tape.
	19-26	A	', OPTION='
	27-30	A	Output tape option, to be used in the call to TIINPT.
	31-55		Not used.
	56-60	A	'SKIP='
	61-65	I	Number of data files to be skipped, on the output tape.
	66-80		Not used.
2	1-8	I	Month/Day/Year of event origin.
	9		Not used.
	10-17	I	Hour/Minute/Second of event origin time.
	18-20		Not used.
	21-25	F	Event latitude in decimal degrees (N=+).
	26-29		Not used.
	30-35	F	Event longitude in decimal degrees (E=+).
	36-37		Not used.

* A = Alphanumeric I = Integer F = Floating Point

TABLE II-3

TISROSPE INPUT CARDS
(PAGE 2 OF 2)

Card Type	Columns	Data Type*	Description
2	38-40	F	Bodywave magnitude.
	41-42		Not used.
	43-45	I	Depth. (km.)
	46	I	NORSAR quality.
	47-50		Not used.
	51-70	A	Region name.
	71-80		Not used.
3	1-5	I	Event identification number.
	6-10	I	Sub-region number.
	11-12		Not used.
	13-15	A	Information source.
	16-20		Not used.
	21-35	I	Site selection table. Column (20+n) should be 1 if data from SRO n is to be processed; 0 if it is not.
	36-39		Not used.
	40	I	Re-sample rate. Defaults to 1, if left blank.
	41-43		Not used.
	44-51	I	Month/Day/Year of edit start.
	52		Not used.
	53-60	I	Hour/Minute/Second of edit start time.
	61		Not used.
	62-65	I	Number of raw data points to be edited.
	66-80		Not used.

* A= Alphanumeric I = Integer F = Floating Point

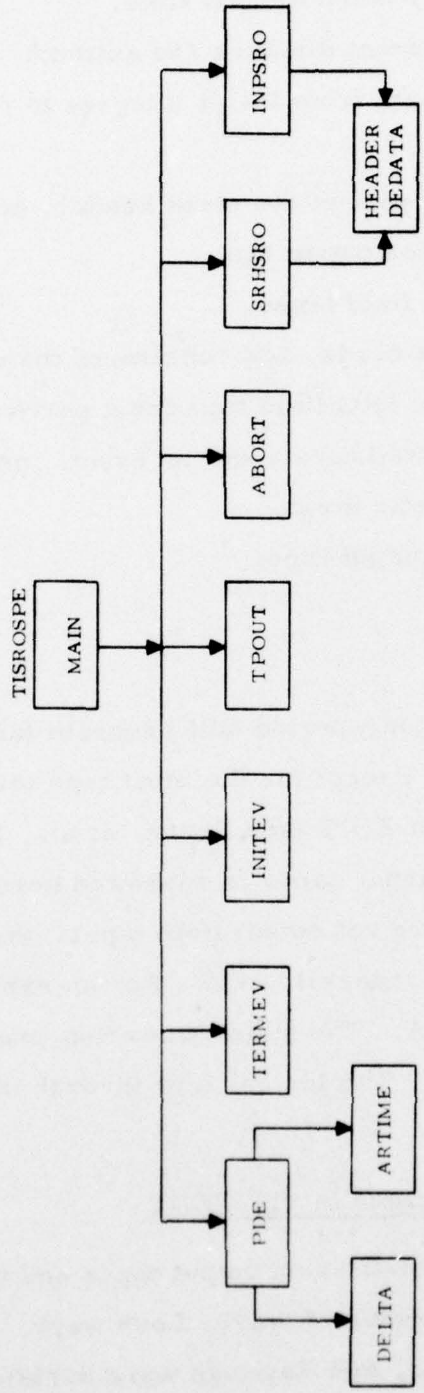

FIGURE II-3
TISROSPE FLOW

Subroutines in TISROSPE

ABORT	-	Writes end-of-files on output tape and unloads all tapes.
ARTIME	-	Computes P wave arrival time.
DELTA	-	Computes event distance and azimuth.
HEADR	-	Converts data from 16-bit integers to floating point, in place.
INITEV	-	Constructs part of the event header, and writes the event header on the output tape.
INPSRO	-	Reads SRO field tapes.
PDE	-	Reads input cards, and constructs the event header.
SRHSRO	-	Searches an SRO field tape for a particular data time.
TERMEV	-	Computes statistics about an event, including sum, power, and arithmetic mean.
TPOUT	-	Initializes output tape.

D. TITRIEDT

TITRIEDT is a long-period edit program for the ALPA, LASA, and NORSAR seismic arrays. Except for the input tape format, TITRIEDT is functionally the same as TIQCEDIT (see Benno, et al., 1971). The section describing the TIQCEDIT input cards is reprinted here, as Table II-4. The input tapes to TITRIEDT are not actual field tapes: they must be in the DP tape format, effective January 1, 1976. For an explanation of the DP tape format, see Appendix A. The subroutines that make up TITRIEDT are listed and described below. The logical flow through them is shown in Figure II-4.

Subroutines in TITRIEDT

ABORT	-	Writes end-of-files on output tapes and unloads all tapes.
ARTIME	-	Computes P wave, S wave, Love wave, and Rayleigh wave arrival times, and Rayleigh wave duration.

TABLE II-4

TIQCEDIT INPUT CARDS
(PAGE I OF 5)

Card #	Field #	Column	Format	Description
1	1	1-4	A4	Array name - 'ALPA', 'LASA', 'NORS', 'ILPA', or 'KSRS'
	2	6-27	22I1	Site flags - 0 = exit, 1 = do not exit
	3	31-40	F10.0	Signal spike level
	4	41-50	F10.0	Signal spike return level
	5	51-60	F10.0	Clipped data level
	6	61-70	F10.0	Noise spike level
	7	71-80	F10.0	Noise spike return level
2	1	1-17	A17	Noise tape number - 'Noise Tape=----' (Columns 12-17 Blank=No noise tape)
	2	19-35	A17	Tape option = 'Option=Initialize' Continue' Skip'
	3	37-40	I4	Number of files to skip on Skip Option
3	1	1-68	68A1	Comment card - only for Initialize Option
4	1	1-18	A18	Signal tape number - 'Signal Tape= ------' (Columns 13-18 Blank=No signal tape)
	2	20-36	A17	Tape option - 'Option=Initialize' Continue' Skip'
	3	37-40	I4	Number of files to skip on Skip Option
5	1	1-68	68A1	Comment card - only for Initialize Option

TABLE II-4

TIQCEDIT INPUT CARDS
(PAGE 2 OF 5)

Card #	Field #	Column	Format	Description
6	1	1-76	76A1	Library tape numbers - 'Library Tape= ------,------.' (9 tapes may be listed, a comma after 6 characters says more tape numbers and a period says the last tape number has been read.
7	1	1-25	25A1	End of tape cards - 'End processing definition'
8	1	1-3	3A1	Flag - 'PDE'=New Event, 'EXI'=Terminate Processing
	2	4	A1	Read override card flag, 'X'=Read Card
	3	6-7	I2	Month of event source time
	4	9-10	I2	Day of event source time
	5	12-13	I2	Year of event source time.
	6	15-16	I2	Hour of event source time
	7	18-19	I2	Minute of event source time
	8	21-22	I2	Second of event source time
	9	23	A1	PDE source time confidence level
	10	25-28	F4.0	Latitude of source in degrees
	11	30	A1	Latitude direction of source ('N' or 'S')
	12	32-36	F5.0	Longitude of source in degrees
	13	38	A1	Longitude direction of source ('E' or 'W')
	14	40-42	I3	Depth of source in kilometers
	15	44-46	F3.0	USCGS m_b
	16	48-50	F3.0	USCGS M_b
	17	52-54	A3	Standard deviation of residual time
	18	56-57	A2	Number of reporting stations
	19	59-66	A8	Information source ('USCGS ')

TABLE II-4

TIQCEDIT INPUT CARDS
(PAGE 3 OF 5)

Card #	Field #	Column	Format	Description
8	20	68-70	F3.0	LASA m_b
	21	72-74	F3.0	LASA M_b
9	1	1-80	80A1	Event description and comments
10	1	1-80	80A1	Event description and comments
11	1	1-4	A4	Data flag - 'DATA'
	2	11-22	3A4	Event specification
	3	23-26	A4	Seismic region
	4	27-30	A4	Edit analyst initials
	5	31-35 I	I5	Calibration code (Currently = 1)
	6	36-40	I5	QC code (Currently = 1)
	7	41-50	F10.0	Estimated S/N ratio
12	1	1-9	9A1	Flag = 'Override'
	2	11	I1	1 = Read azimuth override card
	3	12	I1	1 = Read sample rate override card
	4	13	I1	1 = Read scale factor override card
	5	14	I1	1 = Read segment dump override card
	6	15	I1	1 = Read signal edit override card
	7	16	I1	1 = Read noise edit override card
	8	17	I1	1 = Read new Q.C. values override
	9	18	I1	1 = Read coordinate override card
13	1	1-4	A4	Flag = 'NAZM' (Read card only if necessary)
	2	11-20	F10.0	New signal azimuth
14	1	1-4	A4	Flag = 'NRAT' (Read card only if necessary)
	2	11-20	F10.0	New sample rate

TABLE II-4

TIQCEDIT INPUT CARDS
(PAGE 4 OF 5)

Card #	Field #	Column	Format	Description
15	1	1-4	A4	Flag = 'NSCA' (Read card only if necessary)
	2	11-20	I10	Number of site scale factor cards to be read
16	1	1-10	I10	Site to be scaled (This card is repeated the number of times specified on the 'NSCA' card)
	2	11-20	F10.0	Scale factor for component 1
	3	21-30	F10.0	Scale factor for component 2'
	4	31-40	F10.0	Scale factor for component 3
17	1	1-4	A4	Flag = 'DUMP'
18	1	1-8	2A4	Flag = 'SIGNAL ' (Read card only if necessary)
	2	11-12	I2	New month for edit, 0 = Do not calculate new edit time
	3	14-15	I2	New day for edit
	4	17-18	I2	New year for edit
	5	21-22	I2	New hour for edit
	6	24-25	I2	New minute for edit
	7	27-28	I2	New second for edit
	8	31-40	I10	New edit length in seconds 0 = No signal edit
19	1	1-8	2A4	Flag 'NOISE ' (Read card only if necessary)
	2	11-12	I2	New month for edit, 0 = Calculate noise edit from signal edit
	3	14-15	I2	New day for edit
	4	17-18	I2	New year for edit

TABLE II-4

TIQCEDIT INPUT CARDS
(PAGE 5 OF 5)

Card #	Field #	Column	Format	Description
19	5	21-22	I2	New hour for edit
	6	24-25	I2	New minute for edit
	7	27-28	I2	New second for edit
	8	31-40	I10	New edit length in seconds, 0 = No noise edit
20	1	1-9	9A1	Flag = 'QC VALUES' (Read card only if necessary)
	2	11-20	F10.0	Signal spike level
	3	21-30	F10.0	Signal spike return level
	4	31-40	F10.0	Clipped data level
	5	41-50	F10.0	Noise spike level
	6	51-60	F10.0	Noise spike return level
21	1	1-11	11A1	Flag = 'Coordinates' (Read card only if necessary--this card sets the ALPA coordinates to the configuration before 9-18-70)
22	1	1-12	3A4	Flag - 'EVENT END '

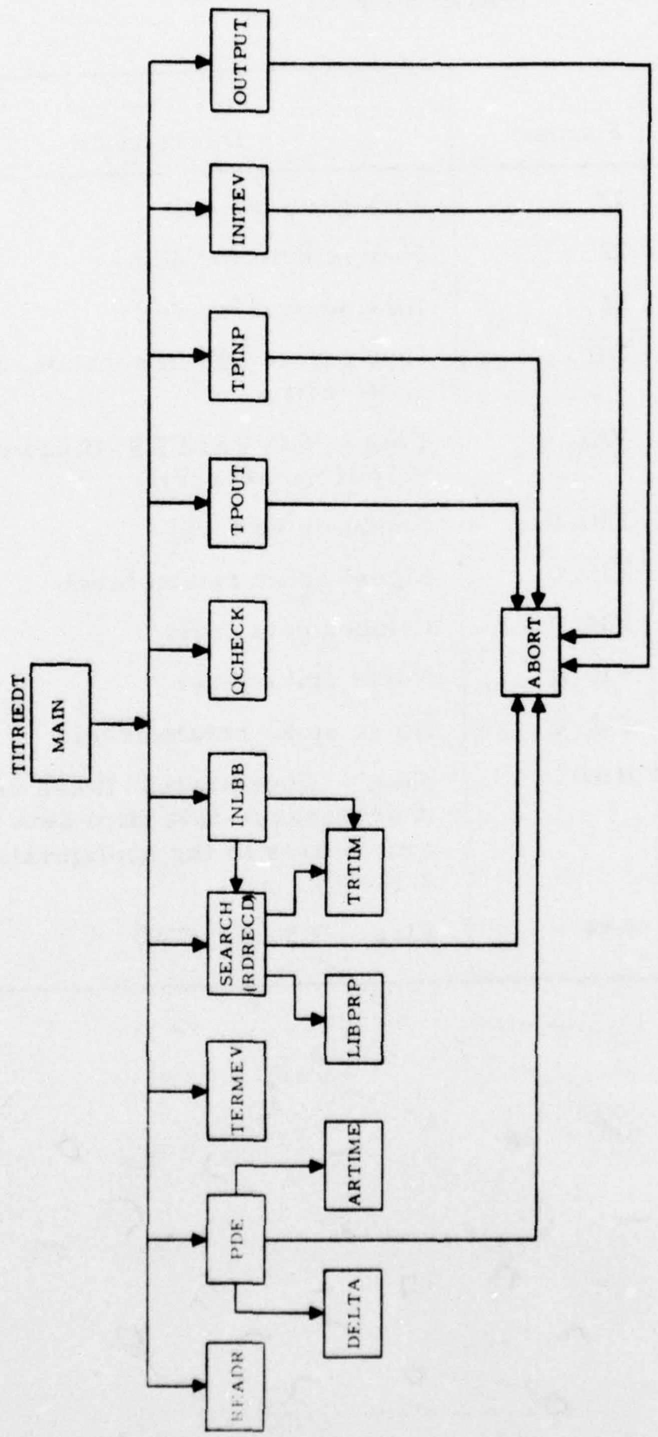

FIGURE II-4
TITRIEDT FLOW

DELTA	-	Computes event distance and azimuth.
INITEV	-	Constructs part of the event header, and writes the event header on the output tape.
INLBB	-	Reads new (1976 and later) ALPA, LASA, or NORSAR library tapes.
LIBPRP	-	Returns the index of data for a particular array, within a new format library tape record.
OUTPUT	-	Writes data on output tapes.
PDE	-	Constructs the event header.
QCHECK	-	Computes statistics on data quality.
READAR	-	Supplies the array configuration part of the event header.
SEARCH	-	Searches a new format library tape for a particular data time.
TERMEV	-	Computes and prints statistics about an event, and prints quality check information.
TPINP	-	Initializes the input tape.
TPOUT	-	Initializes output tapes.
TRTIM	-	Converts data time from the "standard" library tape time format, to seconds into day, and day + year • 1000.

E. TIKSLPED

TIKSLPED is a long-period edit program for the KSRS seismic array. The program is modeled on the TITRIEDT program. For data card format, refer to Table II-4. The subroutines which make up TIKSLPED are listed below along with a brief description of the function each one performs. The logical flow through them is shown in Figure II-5.

<u>Subroutines in TIKSLPED</u>

READAR	-	Supplies the array configuration part of the event header.

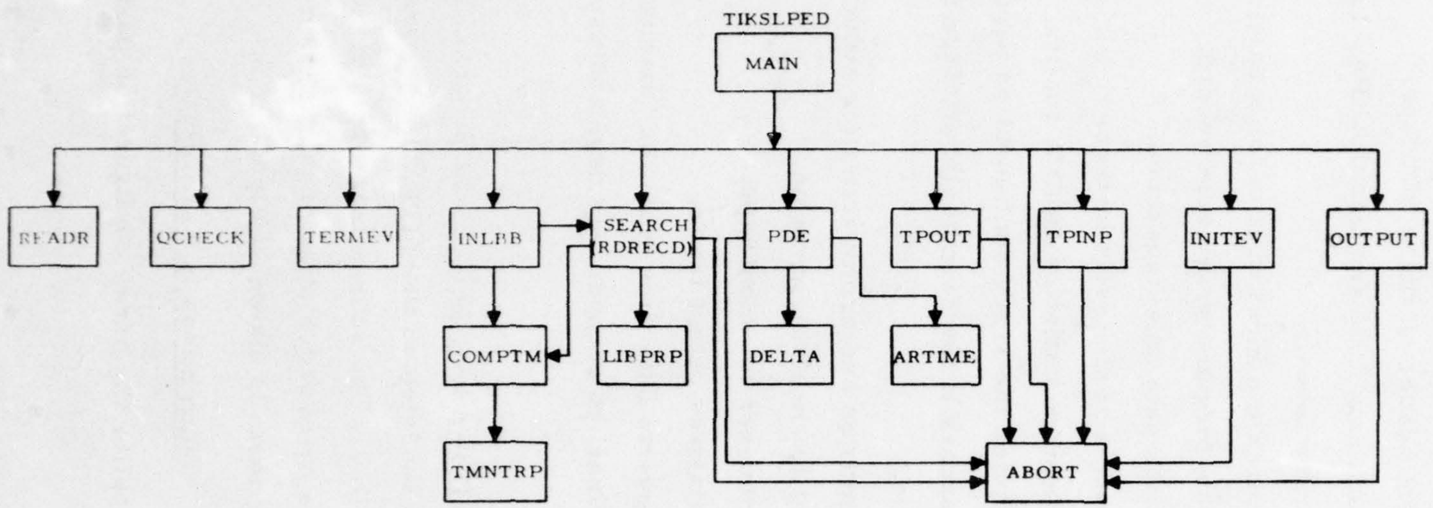

FIGURE II-5

TIKSLPED FLOW

ABORT	-	Writes end-of-files on output tapes and unloads all tapes.
TPINP	-	Initializes the input library tape.
TPOUT	-	Initializes the output tape.
PDE	-	Constructs the event header.
DELTA	-	Computes event distance and azimuth.
SEARCH	-	Searches new (1976 and later) library tapes for the desired record and returns a code with successful/unsuccessful search indication.
LIBPRP	-	Computes index within the input buffer of the array data.
ARTIME	-	Inputs event delta and source time and outputs P, S, Love and Rayleigh wave arrival times and estimated Rayleigh wave duration.
INITEV	-	Initializes output to the noise and signal edit tapes by writing the tape event headers, and initializes needed parameters and indices.
INLBB	-	Inputs data from library tapes.
QCHECK	-	Performs spike and quality checks, computes channel segment sums and powers.
OUTPUT	-	Updates trailer and outputs to tape.
TERMEV	-	Summarizes power anomalies, summarizes segment status frame codes and terminates event tapes.
COMPTM and TMNTRP	-	Calculates time in seconds into day, and day + year•1000 format, from the input tape.

F. NEWMAKE

NEWMAKE is a tape-to-tape copy program. It is a modification of a previously existing program, TAPEMAKE. NEWMAKE takes its primary input from "subset" tapes, via a catalogued subroutine, FETCH. The primary output is on a 7-track tape suitable for input to ISPS. NEWMAKE requires one input card for each trace to be copied. The card format is shown in Table II-5.

TABLE II-5

DATA CARD FORMAT - NEWMAKE

Columns	Data Type*	Field
1-12	A	Event name.
13-20	F	Event latitude, degrees N.
21-28	F	Event longitude, degrees E.
29-36	F	Event depth, km.
37-44	F	USCGS m_b
45-52	F	Station latitude, degrees.
53-60	F	Station longitude, degrees
61-65	I	Seismogram no.
66-70	I	Channel no.
71-75	I	Signal start point.
76-80	I	Number of points of data.

* A = Alphanumeric I = Integer F = Floating Point

The subroutines used in NEWMAKE are listed and described below. The logical flow through them is shown in Figure II-6.

Subroutines in NEWMAKE

AALIAS	-	Eliminates aliasing due to sample rate decimation by zeroing out spectral components above the Nyquist frequency.
DELTA1	-	Computes event distance and azimuth.
FETCH	-	Reads subset tapes.
HDRSET	-	Constructs a PDP-15 event header.
HOLLFP	-	Converts floating-point numbers to Extended Binary-Coded Decimal Interchange Code (EBCDIC).
PLOT4	-	Does printer plots.

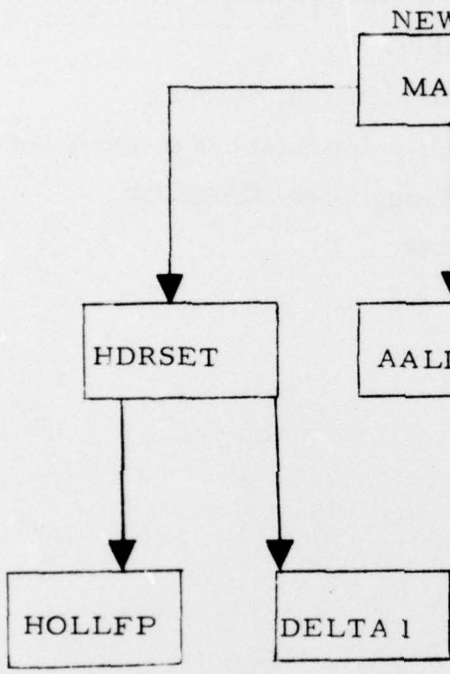

FIGURE II-6

NEWMAKE FLOW

SECTION III
SUGGESTIONS FOR FUTURE WORK

Currently, there are 20 data preparation programs, to perform only a handful of functions. Data preparation procedures can be improved by reducing the number and size of these programs. For example, the introduction of TISROPRG, by eliminating a tape interface, significantly reduced the time needed to evaluate SRO's. The same program also considerably reduced the amount of book-keeping associated with running the SRO programs. Another goal is to reduce the number of tape formats being used. At this time, each program tends to be applicable to only one array, or data format. This phenomenon can be reduced by combining programs and by re-writing them to use standardized tape formats. Development of data preparation procedures will be finished when the seismic data being used at the SDAC can be easily extracted from raw tapes, and placed into a single, standardized data base.

Some specific suggestions:

- Combine TITRIEDT, TIILPEDT, TIKSLPED, and TITDFILT into one program. Add an automatic site selection capability, based on data quality, to eliminate the need for analyst input before running TITDFILT.
- Combine TISROPRG and TISROSPE into one program.
- Convert NORSPOUT, TIKSPED, and TIKSPEAR from DOS to TS44.
- Prepare maintenance documentation for programs that don't already have such documentation. This will require a great deal of work, since the programs involved are many and large. However, the importance of this project cannot be over-emphasized.

- Develop and implement a system for keeping track of tapes generated by Texas Instruments, Inc. projects at the SDAC.

More than any other gen program, DATAPREP embodies the latest ideas in data preparation (correction for system response, cepstrum beamforming, etc.) In order to make the program more general, and therefore more useful, I suggest that we should:

- Add a capability to handle a variable number of input data channels.
- Change from card output to tape output.
- Add an automatic site selection capability, based on data quality, to eliminate the need for analyst input before the DATAPRP1 portion of the run.
- Change the method of specifying site locations in the event header, to use a separate reference sensor for each array or sub-array.
- Make the event origin time an input parameter. Compute separate array or sub-array arrival times by computing travel times. The current method of determining the signal arrival time is that the analyst inputs the number of points displacement into the data record.
- Use an automatic signal detector to prepare for beamforming within arrays or sub-arrays. Currently, the analyst inputs one signal start time for all channels, and beamforming is done using geographically determined lag times and a plane wave assumption.

SECTION IV
REFERENCES

Benno, S. A., et al., 1971, Documentation of Off-Line Array Evaluation Software Package, AFTAC Contract Number F33657-69-C-1063, Texas Instruments Incorporated, Dallas, Texas.

Benno, S. A., et al., 1971, Documentation of Long-Period Experiment Software Package, AFTAC Contract Number F33657-69-C-1063, Texas Instruments Incorporated, Dallas, Texas.

Ringdal, F., J. S. Shaub, and D. G. Black, Documentation of the Interactive Seismic Processing System (ISPS), Texas Instruments Report Number ALEX (01)-SD-75-01.

Sax, R. L., 1976, Design, Simulated Operation, and Evaluation of a Short-Period Seismic Discrimination Processor in the Context of a World-Wide Seismic Surveillance System, Technical Report No. 9, Texas Instruments Report No. ALEX (01)-TR-76-09, AFTAC Contract Number F08606-76-C-0011, Texas Instruments Incorporated, Dallas, Texas.

Strick, E., 1970, A Predicted Pedestal Effect for Pulse Propagation in Constant-Q Solids, Geophysics, <u>35</u>, 387-403.

APPENDIX A

NEW LIBRARY TAPE FORMAT FOR ALPA, LASA, AND NORSAR

The library tape format for each of the seismic stations and arrays has been described in previous documents. The following describes the new library tape format for ALPA, LASA, and NORSAR, effective January 1, 1976.

These tapes are produced by the SDAC real-time system, and are known as DP tapes. The tapes are nine track, and are recorded at 1600 bits per inch (BPI). Each contains three files: the header label, the data, and the trailer label.

The format of the seismic data record is shown by Figure A-1. Each record consists of a Record Header and a Record Body. The record header begins with the characters 'DA ' (Extended Binary-Coded Decimal Interchange Code (EBCDIC)).

The second field of the header is the number of arrays contributing to the record. This number is equal to the number of array ID/array length pairs in the header. Once a new array has been added to the Network, its entry remains in the record header until that array is removed from the Network. If the data from an array is not present for one or more seconds, the length of data for that array is encoded as zero, and the space in the record body normally occupied by that array's data is omitted. For example, if array 3 is missing, than array 4 data will be adjacent to array 2 data in the record body. The number of arrays is likely to be less than eight.

The Array ID field of the Record Header is a 4-byte field in EBCDIC. The Array ID's to be used in the Record Header are as follows:

RECORD HEADER

'DA '	# Arrays Contributing to Record Body	Array 1 ID (EBCDIC)	Length in bytes of Array 1 Data	Array 2 ID	Length in bytes of Array 2 Data	....	Array N ID	Length in bytes of Array N Data
4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes		4 bytes	4 bytes

RECORD BODY

Time Code	Array ID (ASCII)*	Block Status	SP Status	SP Data	LP Status	LP Data	....	Array N Data
8 bytes	3 bytes	1 byte						

← Array 1 Data → (Time Code through LP Data)

* American Standard Code for Information Interchange

FIGURE A-1

SEISMIC DATA FORMAT

Data Type	ID
ALPA	'ALP '
LASA	'LA0 '
NORSAR	'NA0 '
KSRS	'KSR '

KSRS data has been assigned an Array ID, but, at this time, no KSRS data will be on the tapes.

The 8-byte Time Code field of the Record Body contains the Raw Timing Word, as shown in Figure A-2.

The Array ID field of the Record Body is a 3-byte field of ASCII characters. The Array ID's are the same as in the Record Header listed above.

The 1-byte Block Status field of the Record Body is as follows:

Bit 0 = 1	if data is absent
Bit 1 = 1	if transmission error
Bits 2 - 7	not used.

The raw data for all three (ALPA, LASA, and NORSAR) arrays will be in gain-ranged format. The bit configuration of the 16-bit data values in the gain-ranged format is:

Bits 0 - 3	GAIN CODE, G
Bits 4 - 15	INTEGER VALUE.

The Gain Code must be a value G such that $0 \leq G \leq 10$. The following formula can be used to decode the gain-ranged data word:

$$(12\text{-bit value}) \bullet 2^{(10-G)}.$$

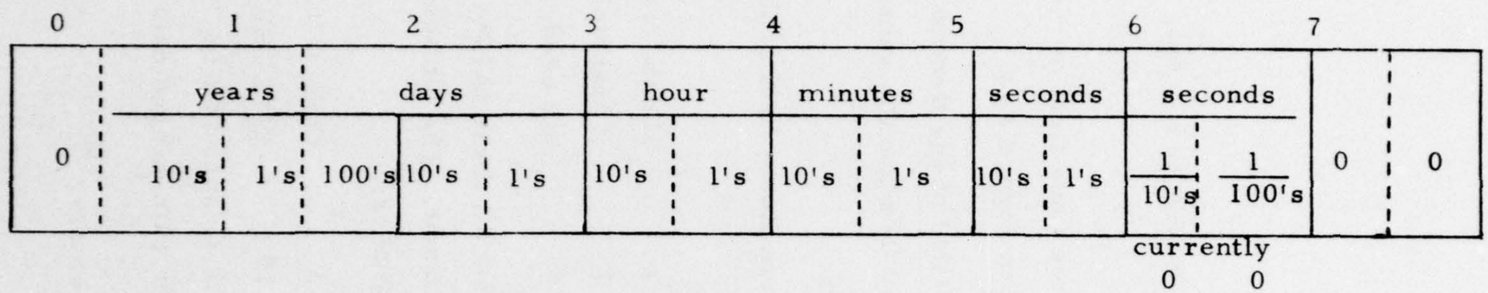

FIGURE A-2
RAW TIMING WORD (8 BYTES)

ALPA DATA:

There will be only LP ALPA data, in the following format:

SITE STATUS - 3 bytes

19 bits - 1 for each site

5 bits of padding.

INSTRUMENT STATUS - 10 bytes

19 fields of 4 bits each, followed by

4 bits of zero padding

Bit 0 = 1	if instrument 1 is bad
Bit 1 = 1	if instrument 2 is bad
Bit 2 = 1	if instrument 3 is bad.

DATA - 114 bytes

57 16-bit gain-ranged samples (3 per site).

On some tapes ALPA beams may be added beyond raw data fields. The order of the ALPA sites is as follows:

3-23

3-2

3-3

3-34

3-4

2-3

3-1

1-1

2-4

3-45

3-5

2-5

3-56

3-6

3-16

2-6

2-1

3-12

2-2

NORSAR DATA:

There will be SP followed by LP NORSAR data. The format will be as follows:

SP DATA - 68 bytes

6 bytes	Three 2-byte Channel ID's
2 bytes	A 1-bit Repeat Indicator, followed by 15 bits of zero padding
60 bytes	Ten frames of data. Each frame consists of three 16-bit words, corresponding to three SP channels. Data is in gain-ranged format.

LP DATA - 142 bytes

STATUS - 10 bytes

22 fields of 3-bits each

13 bits - zero padding

1 bit repeat indicator.

DATA - 132 bytes

66 16-bit gain-ranged words (3 components per site).

The order of LP NORSAR sites is:

01A, 01B, 02B, 03B, 04B, 05B, 06B, 07B, 01C, 02C, 03C, 04C, 05C, 06C, 07C, 08C, 09C, 10C, 11C, 12C, 13C, 14C (low gain).

LASA DATA:

There will be SP followed by LP LASA data. The format will be as follows:

SP DATA

BEAM STATUS FIELD - 20 bytes

This status is logged at a 1-Hz rate.

13 12-bit fields representing subarrays A0 through D4, in ascending order.

Bit 0 = 1	if the beam is absent
Bit 1 = 1	if calibration instead of beam data is present.
Bits 2 - 11	each bit corresponds to a sensor that contributes to the beam; a bit is set to 1 if its related sensor was dead longer than half of the current second.

4 spare bits.

RAW DATA STATUS FIELD - 4 bytes

This status is logged at a 1 Hz rate.

6 3-bit fields for 6 SP data sensors.

Bit 0 = 1	if there is no data
Bit 1 = 1	if calibration is in progress
Bit 2 = 1	if the LDC operator has declared the sensor bad

14 spare bits.

INSTRUMENT STATUS FIELD - 8 bytes

The status is logged at a 10 Hz rate. It applies only to the SP raw (unbeamed)data. There are 10 6-bit subfields, each subfield representing 0.1 seconds. A bit is set to 1 when data from the corresponding sensor is bad due to a glitch or parity error.

DATA - 380 bytes

10 304-bit frames each representing 0.1 seconds and containing 13 16-bit SP beam data values and 6 16-bit SP raw (unbeamed) data values (see Figure A-3).

SP beam data values are 14-bit numbers left justified in the 16-bit field. Negative data values are in 2's complement form.

SP raw data values are right justified in the 16-bit field.

The order of the samples is: A0, B1, B2, B3, B4, C1, C2, C3, C4, D1, D2, D3, and D4 beams, followed by D2-Z, D2-N, D2-E, D2-Z (LG), D2-N(LG), and D2-E(LG) raw (unbeamed) data samples.

LP DATA

RAW DATA STATUS - 16 bytes

30 4-bit subfields for the 30 LP sensors (10 sites, 3 components each)

Bit 0 = 1	if data is absent
Bit 1 = 1	if calibration in progress
Bit 2 = 1	if software declared data bad due to glitch or parity error
Bit 3 = 1	if LDC operator declared data bad

8 spare bits.

DATA - 60 bytes

30 16-bit data values in gain-ranged format.

The order of the LP LASA samples is as follows: A0-Z, A0-N, A0-E, C1-Z, C1-N, C1-E, C2-Z, C2-N, C2-E, C3-Z, C3-N, C3-E, C4-Z, C4-N, C4-E, D1-Z, D1-N, D1-E, D2-Z, D2-N, D2-E, D3-Z, D3-N, D3-E, D4-Z, D4-N, D4-E, C2(LG)-Z, C2(LG)-N, C2(LG)-E. Note the addition of a C2 (not low-gain) sample. Also notice that there are now only 10 LP sites, hence 30 sensors.

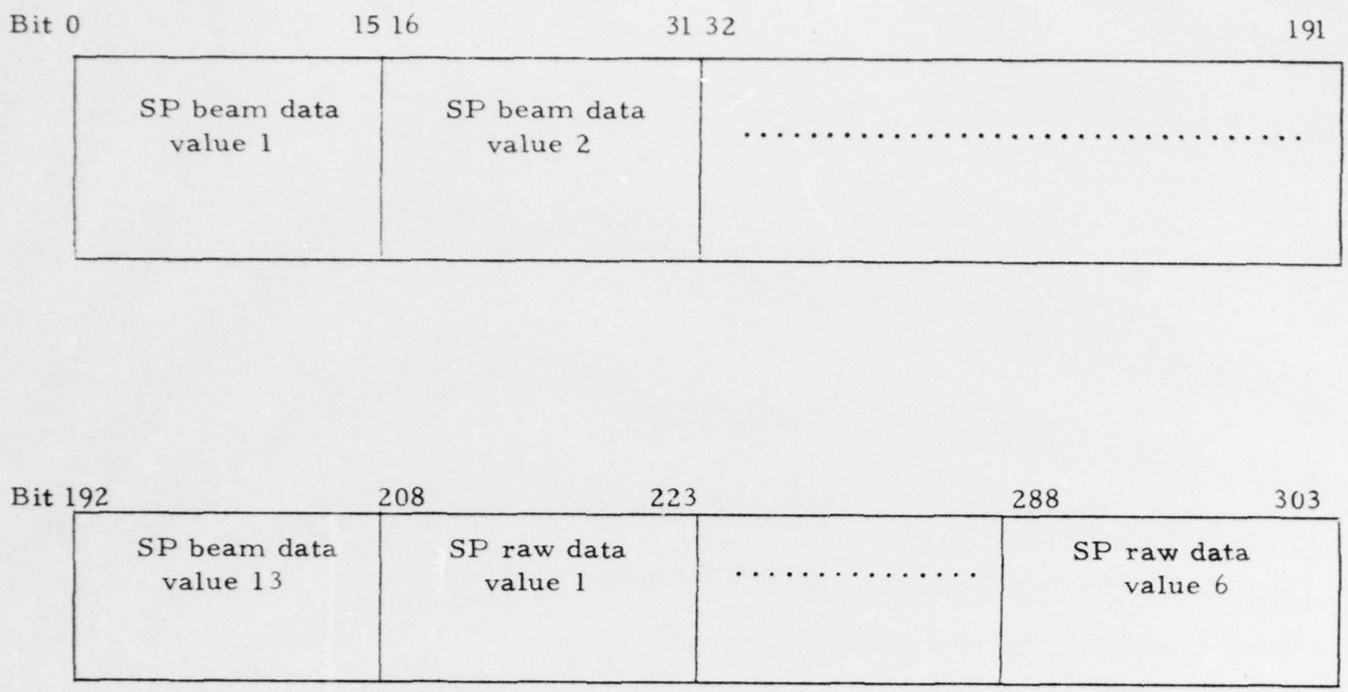

FIGURE A-3

LASA SP DATA FRAME